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CHUCKING AND WORK HOLDING.

Abstract of paper presented to the Institution, Birmingham Section, 17th December, 1930, by E. W. Field, M.I.P.E., and J. H. Garnett, A.M.I.Mech.E., M.I.P.E.

A WORK holding device may be defined as some form of mechanical structure which will grip a component or components in such a manner as the shape of the work will allow and thus present the surfaces to be machined to the cutting tool, due regard being paid at all times to the possibility of distortion of the work and the necessity for holding it with sufficient rigidity to resist the pressure exerted by the cutting tools.

The primary object of a work holding fixture is to secure the work under the conditions enumerated, albeit the various conditions under which tools are applied will naturally have some effect upon the design of the fixture. These conditions may be summarised as (1) work rotating with the tool stationary; (2) work stationary with the tool rotating; (3) work reciprocating with the tool stationary; (4) tool reciprocating with the work stationary; and (5) both work and tool rotating.

In the first set of conditions may be included lathes and boring mills. The second set includes milling and drilling machines; the third set planing machines; the fourth set shaping, slotting and similar machines; and the fifth set grinding machines, thread millers, and deep hole drilling machines. In each instance, movement by feed is disregarded for the purpose of this consideration.

Work Holding Effects.

More difficulties are probably met with when the work has to be rotated than under any of the other conditions, and viewed from this angle it is logical to give first consideration to work holding devices as applied to lathes. With an ordinary jaw chuck, three classes of tool pressure have to be considered, namely, torque, bending moment, and end thrust. To indicate these conditions, a series

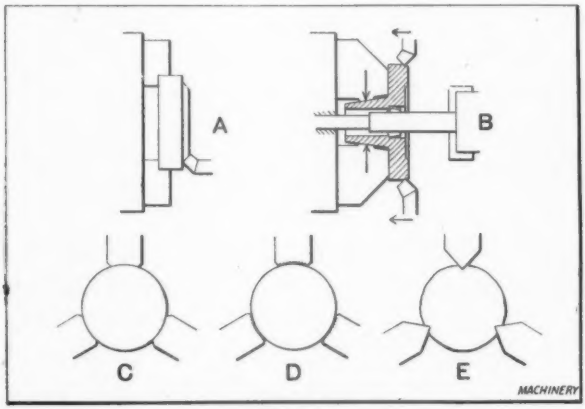

FIG 1

of illustrations are introduced, of which Fig. 1 is intended to demonstrate torque effects. In the examples shown at *A* and *B*, there is practically no overhang and plain jaws as shown at *C* would be fairly effective. Jaws with serrated gripping faces, as shown at *D*, would be a decided improvement, however, while in the case of very rough work, knife edge jaws, as shown at *E*, would give a greatly increased driving effect. At the same time, increase of overhang would nullify the advantages to be derived from a knife edge type of jaw.

The bending moment effect is illustrated in Fig. 2, the position of the tool and direction of feed at *A* being greatly exaggerated more clearly to indicate the resultant bending moment. In such cases the ratio $H : h$ should be kept as low as possible. Serrated jaws have no advantage over the plain jaw, when the cutting

pressure produces a pure bending moment, as the tool pressure would tend to embed the serrations in the work and so allow some rocking movement. Special jaws, as shown at *B*, would be an improvement. In this case each of the three jaws has two swivelling

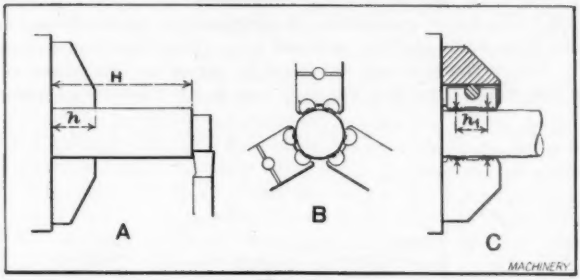

FIG 2

insets, the faces of which are serrated and, by their radial movement, more or less conform to the irregularities of the shape of the work being gripped. Should the work be irregular in length, jaws with rectangular swivelling insets pivoted across the jaw would improve matters, as a two-point support, indicated at h_1 in the view at *C*, would be provided.

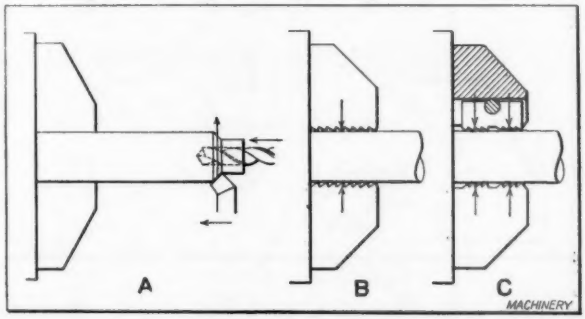

FIG. 3.

The third condition combines end thrust with torque and bending moment, at *A*, Fig. 3, and while end thrust to some extent counteracts bending moment, it introduces the need for a serration of the buttress thread type, as shown at *B* and *C*.

Chucking Effects. Hand and Power.

From the examples shown, it will be appreciated that the work holding effect of a jaw chuck depends upon three principles, viz.,

the power applied, the design of the chuck, and the form of the jaw. Accepting these principles, the difference in conditions between a hand operated chuck and a pneumatic or hydraulically operated chuck may be considered.

In regard to torque it may be pointed out that on the hand operated chuck the application of chucking power is effected before the machine starts and the jaws are in a certain position and cannot move. When the jaws are actuated by air or oil the power acts on them the whole time and the jaws can move. The effects are illus-

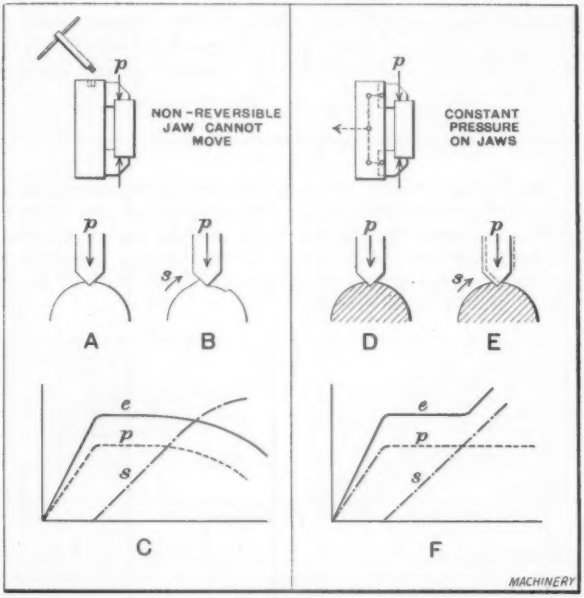

FIG 4.

trated in Fig. 4, the diagrams to the left showing the effect of hand operation and those to the right the effect of power operation. At *A* and *D* the jaw is assumed to have embedded itself to some extent into the work. If the cutting pressure *S*, shown at *B* and *E*, exceeds a certain value, the work begins to slip. In the case of a hand operated chuck, the work becomes loose with the result shown diagrammatically at *C*. Here *e* is the work holding effect; *p* is the clamping pressure and *s* the cutting pressure. It will be appreciated that the work holding effect *e* can remain constant, providing there is not too much cutting pressure. On the other hand, it can

never improve and if the work begins to slip it will definitely get worse.

The power operated chuck is shown under the same set of conditions, except that in this case there is a constant load behind the chuck jaws. When excessive tool pressure is applied, the tendency of the jaw is to embed itself further into the work on account of the continued pressure exerted by the operating cylinder.

On comparing the power diagram F with the diagram C it will be seen that whereas the line s, indicating the cutting pressure in the case of the hand-operated chuck, crosses the line e, indicating the work holding effect, in the power diagram the lines never cross, the conclusion being that the work holding effect on an air or oil chuck can remain constant, and providing the jaws are properly designed it can never become worse under cut. In point of fact, the work holding effect increases with increased cutting pressure, inasmuch as the jaws bed deeper into the work until a specific pressure on the jaws and on the cutting tool are in equilibrium.

Effects of Axial Thrust and Bending Moment.

Power chucking offers the same advantages under axial loads as illustrated by Fig. 5, A and B, the former showing the conditions encountered with a hand chuck and the latter with an air operated

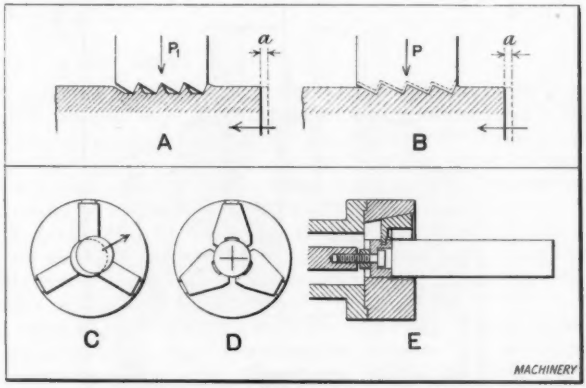

FIG. 5.

chuck. The distance a represents slip which is likely to occur due to axial thrust under the respective conditions of gripping p_1 and p.

Similar results are obtained under a bending moment, and in this connection it may be mentioned that a characteristic of the air or oil-operated chuck is that it is operated by a central draw-bar. This affords the possibility of applying a simple and very effective collet type of chuck similar in arrangement to that shown at E.

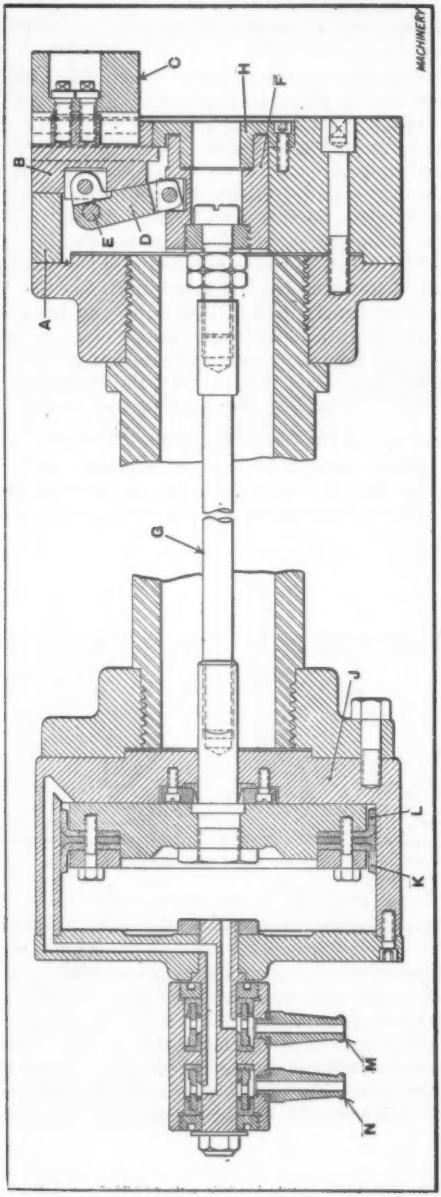

FIG. 6.

In this case the jaws are closed by drawing them backward in a taper housing, a method which obviates the danger of tilting or lifting the work out of the chuck. The jaws almost entirely surround the work, as indicated at *D*, thus eliminating the condition shown at *C*.

The advantage of increasing work holding effect with increasing cutting pressure is greater even than the sketches demonstrate, since if the jaws are correctly designed for the job the clamping power need not be nearly so large as in the case of hand clamping.

How far this principle has already been exploited is best illustrated by stating that air chucks are in use for the transmission of loads up to 300 horse-power. In every non-reversible mechanism, as exemplified by the hand chuck, 50 per cent. of the power applied is lost in friction. Indeed, it is not too much to say that 50 per cent. is not sufficient in a non-reversible mechanism which is subjected to chatter, vibration and shock. In order to be safe friction must consume at least 70 per cent. of the power input, and it is for this reason that a length of gas piping is commonly employed by the operator using a hand chuck.

Having thus illustrated some of the advantages of the power chuck it remains to say that no stress has so far been laid on the ease of operation of the air chuck, nor its time saving capabilities. These points, however, will be made clear during the remainder of the paper.

A Typical Air Chuck.

The principle on which air chucks operate will next be considered. The first example is by F. Pratt & Co. Ltd., Halifax, and is shown in general arrangement in Fig. 6. The chuck body is made of cast steel and is designed to be virtually dust and dirt proof. All moving parts are made of heat-treated nickel chrome steel. The three jaws each comprise a slide which is fitted with a loose member. This can be made for either internal or external gripping. The loose jaws are attached to the slides by set screws and pads, being located by fine serrations which permit of adjusting the jaws to suit the diameter of the work to be gripped.

To actuate the jaws toggle links are employed. These are hinged and are actuated to apply the clamping pressure by a piston which is attached to a draw-bolt, the hole in which the piston operates being closed from the front of the chuck by an adapter. The air cylinder is attached to the rear end of the machine spindle. It is a cast-iron member and is fitted with a piston rod of heat-treated nickel chrome steel. Suitable packing is provided which adjusts itself to counteract the air pressure.

The air supply is controlled by a hand or foot-operated valve and passes to the pressure cylinder through either of two passages. One passage leads to the rear side of the piston and forces it towards

the chuck, thus opening the jaws. The other passage leads to the front side of the piston, forcing it away from the chuck and closes the jaws. In practice it is usual to introduce a reducing valve in the air supply for the purpose of regulating the air pressure, thus enabling work to be gripped with just the required amount of pressure to resist the action of the tools and yet without distortion.

The chuck described is typical of air-operated jaw chucks at present on the market, although there are other very successful types in which the method of actuating the jaws is slightly different. In one case the jaw slides are coupled to the toggle links by a rack and gear quadrant, and in another example the piston member has a series of taper grooves. These engage corresponding projections on the jaw slides and operate them on the wedge principle.

Air Operating Cost.

The volume of air required depends entirely upon the number of times per hour that the various chucks are operated. A single cylinder belt-driven air compressor of three inches bore by three and a half inches stroke should, however, be ample to operate up to a dozen ten-inch diameter air cylinders. A compressor of this size supplies 5.5 cubic feet of free air per minute when running at 500 r.p.m. The cost of such a compressor, together with an automatic air governor, loose pulley and belt striking gear, and a fifteen inch diameter air receiver with a safety valve, pressure gauge and drain cock, amounts to approximately £20. The only additional expense is that incurred in putting the plant down and installing the necessary piping to carry the air to the various machines.

With a larger number of chucks the cost would be increased, but not in direct proportion. In the present instance the compressor calls for the use of one and a quarter horse-power at the flywheel and is sufficient to maintain a working pressure of 100 lb. per square inch.

It may be mentioned that in the works of Broom & Wade, Ltd., High Wycombe, a compressor plant of the size just described is used to operate three fourteen-inch chucks and four ten-inch chucks, the air also being used to blow swarf away on fourteen machines. The compressor is running light for fully 25 per cent. of its time, the running cost amounting only to the power consumed and a pint of lubricating oil per week. An indication of the saving in time is effected in this plant by using air chucks is given by the fact that a hundred gun-metal bearings are machined per hour in an air-equipped capstan lathe, representing an increase of 33 per cent. over the production obtained when a hand chuck was used.

Hand Chucks for Castings.

The gripping of castings and forgings whether by hand or mechanically often presents difficulties on account of the shape and nature of the work to be machined. In cases where these two factors do

not need to be considered the difference between the three-jaw hand-operated self-centring chuck, and the air chuck is conveyed by the statement that with air at 80 lb. per square inch pressure and using an air cylinder of equal diameter to the chuck the latter will give at least an equivalent grip to a hand-operated chuck of equal size, utilising the same chuck jaws, and tightened by the aid of a tube two feet long on the end of the ordinary chuck key. It may be mentioned that air-operated chucks are being used for holding alloy steel ingots up to twenty-three and a half inches in diameter in an ingot parting off machine. This transmits 130 to 150 horse-power and, with a cutting speed of thirty-four feet per minute and a chip section of 0.62 square inch the tools exert a pressure on the work of more than 130 tons.

Whatever the power of the grip the question as to whether it is sufficient to hold the work is one that is largely determined by the design of the jaws and their ability to bite into the work. In the case of hand-operated chucks this feature is demonstrated by Fig.

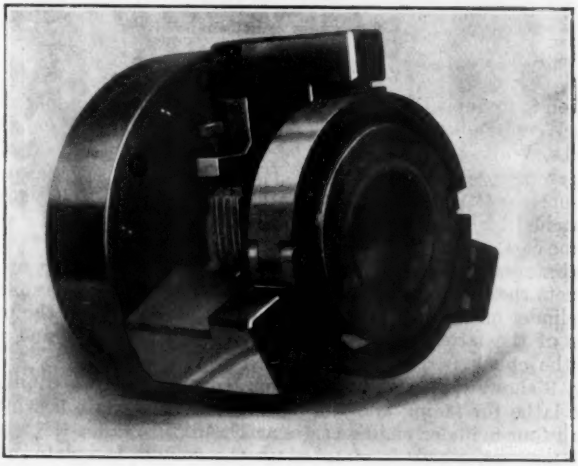

FIG. 7.

7, which shows a quick-loading arrangement for holding aero-engine cylinder heads in a standard Coventry chuck. The casting is of awkward shape and, although not particularly robust, it must be gripped firmly and accurately to withstand the action of boring and heavy cutting by wide form tools used for finishing the bottom of the bore.

To support heavy work that overhangs the chuck the bell housing can often be applied with advantage. Fig. 8 shows a Ward com-

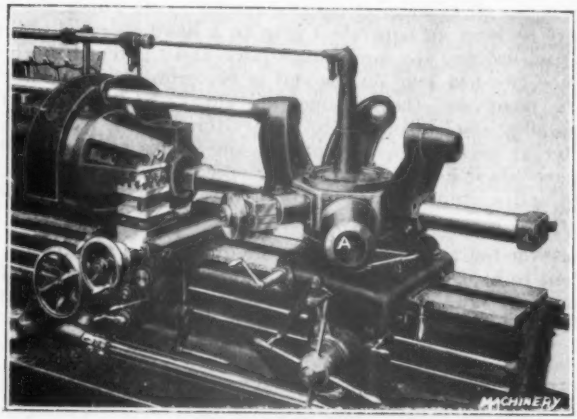

FIG. 8.

bination turret machine tooled for machining the aluminium cylinder for a Westinghouse vacuum brake, as used on heavy commercial vehicles, Widia tools being employed with a cutting speed of 750 feet per minute. The forward end of the casting is gripped in a hand-operated three-jaw chuck to the face of which a bell housing is attached. This is provided with three adjustable screws at the extreme end, which are used to support the outer end of the cylinder immediately in front of the cutting tools. The housing in no way obstructs the use of the chuck, and loading is facilitated by placing the cylinder on the plug *A*. This is carried by the turret, the movements of the latter being utilised to remove the work and place it in the chuck.

Fig. 9 shows a special fixture mounted on a Ward combination turret lathe for facing and line boring the crankshaft bearings in a small four-cylinder engine casting. The fixture takes the form of a bell housing, which is attached to the spindle faceplate, and is supported at the open end by a three-roller support. The rollers are housed at *A*-*B*-*C*, and provide a bearing for a machined beading. The fixture is run at a high speed, and to compensate for variations in diameter due to expansion the rollers have a limited amount of adjustment. This is effected by swinging eccentric studs on which the rollers are carried through the medium of worm gearing, operated by the hand screws *D*. The cylinder block is located in the fixture on a flat seating, and short spigots which engage the two end bores.

Quick-acting bolts, as seen at *E*, pass through the spigots and hold the work when set. Having secured the clamps, the work is supported at each side by the spring loaded plungers *F*. These are held

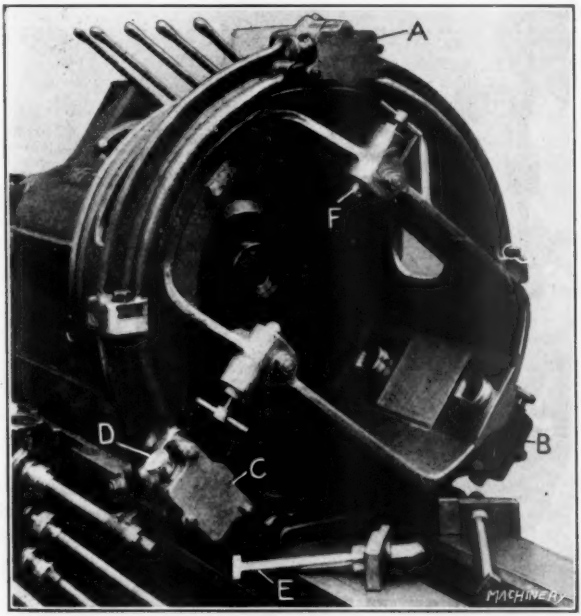

FIG. 9.

clear of the work when loading by giving the handle a quarter turn, and after making contact with the work they are locked by the screws seen at the front end of the fixture.

Indexing Chucking Fixtures.

Before leaving the subject of hand-operated chucks and fixtures, mention may be made of the use of an indexing arrangement. By adopting this procedure a saving in time and effort often results, since a greater amount of work is done at each individual handling of the work piece. There are cases also where an indexing arrangement enables the machine to be utilised to better advantage. This point is illustrated by Fig. 10, which shows a 6½-inch centre Ward capstan lathe set up for machining the bores at both ends of a small connecting rod.

Prior to the capstan lathe operation the rods are faced on a milling machine to provide true clamping and locating surfaces on a plate which is mounted eccentrically on the main faceplate. The

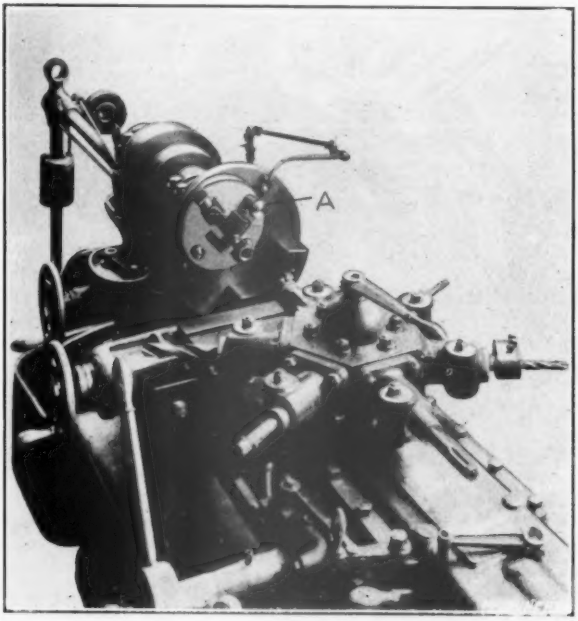

FIG. 10.

eccentric plate has two index positions, to bring either the big or small end boss in line with the spindle centre, each position being determined by a taper plunger *A*, which engages hardened steel bushes in the main faceplate. The tools are so arranged that the two bores are dealt with, and a complete connecting rod is produced at one chucking and one revolution of the turret.

An indexing fixture is shown by Fig. 11 on a Ward capstan lathe. The component is a geared pump body, which is mounted on an eccentric secondary faceplate, so arranged that each of the gear centres is, in turn, presented to the turret tools. The layout differs from the previous example in that it requires a double revolution of the turret completely to machine the one casting. Both bores are machined with the same tools at the same setting, so that consistent accuracy is readily obtained. In connection with

indexing fixtures it should be mentioned that with the advent of high cutting speeds, such as are necessary when using tungsten carbide cutting tools, close attention must be paid to balance.

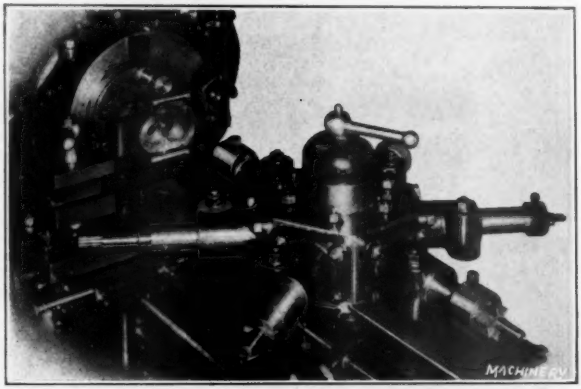

FIG. 11.

At the works of H. W. Ward & Co. Ltd., where machines are frequently tooled to run at speeds of as high as 1,500 r.p.m., such fixtures are dynamically balanced to close limits.

Mechanically Assisted Chucks.

As an alternative to the purely mechanically operated chuck the effort required to chuck a work piece can often be materially reduced by the use of springs. This method is illustrated by Fig. 12, which shows a Ward geared head capstan lathe fitted with a spring operated expanding mandrel. The machine is tooled for the production of gilled rings for water cooling towers. These are not bored but require machining on short spigots at each end. For this reason there is only one turret tool which is used to size the front spigot, the rear spigot being sized by the front cross slide tool. Both spigots and end faces are rough machined by gang tools mounted on the rear cross slide tool post.

The work holding arrangements comprise a mandrel with three equally spaced expanding plungers at the front end and three at the rear end. The work is placed on the mandrel with the plungers collapsed and is gripped when they are allowed to expand. These movements are controlled by a foot lever which is brought close to the working position. The depression of the foot lever tilts a weighted lever *A* and, through the medium of a tie rod *B*, and a

collar attached to the hinged lever *C*, acts on a draw-bolt passing through the centre of the machine spindle.

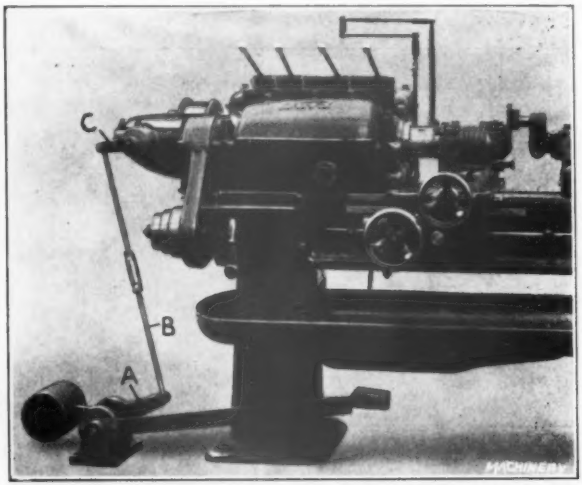

FIG. 12.

Air Chuck Applications.

The ability to regulate the air pressure, and consequently the strength of the grip exerted by the chuck is often important. Even on a comparatively rigid piece of work the inevitable effect of a heavy grip must be to set up stresses which may cause distortion when the work is removed from the chuck. To obviate this it is common practice even with a hand operated chuck to ease the gripping pressure between roughing and finishing cuts. With the air operated chuck this can be accomplished by hand or automatically as illustrated in Fig. 13. This shows a Montforts automatic chucking machine fitted with a Forkardt air chuck pressure gauge and reducing valve. The chuck is operated by one hand lever, and for varying the air pressure there is a second control lever which can be engaged by hand or by means of a cam on the drum *A* which regulates the cycle of operations of the machine. The cam will automatically apply a pre-determined reduced pressure when a finishing cut begins, thus enabling the work to adjust itself and to be machined under normal conditions. The advantage of the power method is that the reduced pressure is always uniform and can be set to the minimum amount consistent with safety.

Although normally intended to operate with a self-centring action, the air chuck can be so arranged that while moving simultaneously, the jaws will automatically adjust themselves to suit

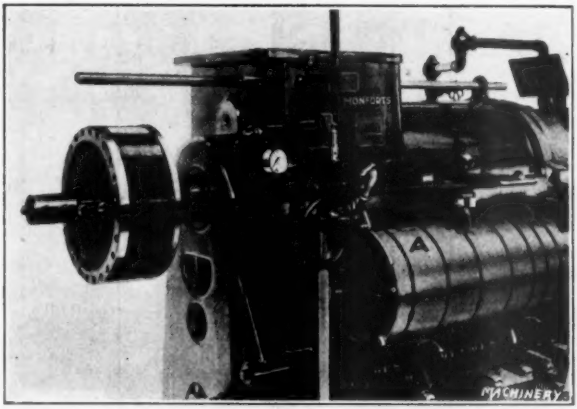

FIG. 13.

irregularities on the surface to be gripped. In such cases the chuck looses its self-centring feature by the equalising action of the jaws has a definite value in producing accurate work. The effect is shown by Fig. 14 where two Forkardt air chucks are illustrated in cross section. In both instances the chuck is required to grip a work piece that is definitely located in relation to the rotational axis, in one case by a plug adaptor and in the other by a pair of cone centres. These serve to hold the work concentric, the only requirement of the chuck jaws being to transmit drive. The chucks are fitted with jaws of the rack slide type which are operated through the medium of toggle levers and the central sliding member *A*, the latter being coupled by a draw-bolt to the air cylinder. In a self-centring chuck this sliding member has a parallel bearing in the centre of the chuck, and as a consequence each of the jaws is moved an equal distance when the member is operated. To provide an equalising effect, however, the sliding member is barrelled and has a spherical seating at the point where it is coupled to the draw-bolt. As a result, on closing the chuck jaws, the member can swivel and automatically compensate for any slight irregularities in the diameter of the surface to be gripped.

Air chucks used for second operation work on motor end shields are designed to give a face grip. For the first operation on such pieces, Alfred Herbert, Ltd., have adapted the air chuck on the

lines shown by Fig. 15. In this instance, the work is stove enamelled before machining, so that, in addition to gripping the work without distortion, it was essential not to mark the surface. The machining

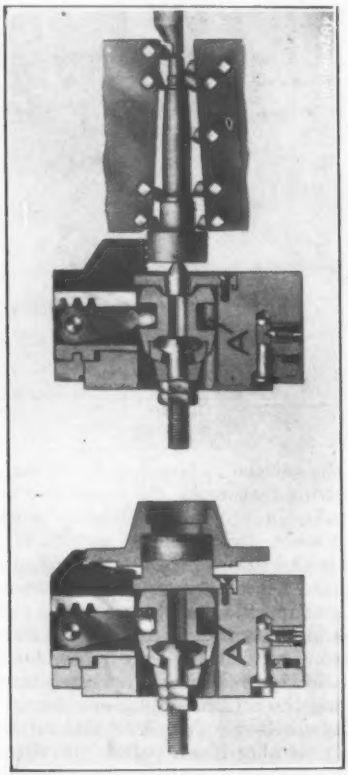

FIG. 14.

consists of facing and boring the large diameter which is required to be round and concentric within 0.002-inch. The chuck is of the three-jaw type, and has the loose top member on one jaw set back so that the small irregular-shaped boss at the end of the casting can be gripped with the large boss running concentric. Actual contact with the work is made by the points of cone-ended screws that are adjustable for the purpose of centring, the third off-set

jaw having two screws set at a slight angle to ensure the work nesting accurately in the jaws. The latter only take a light grip

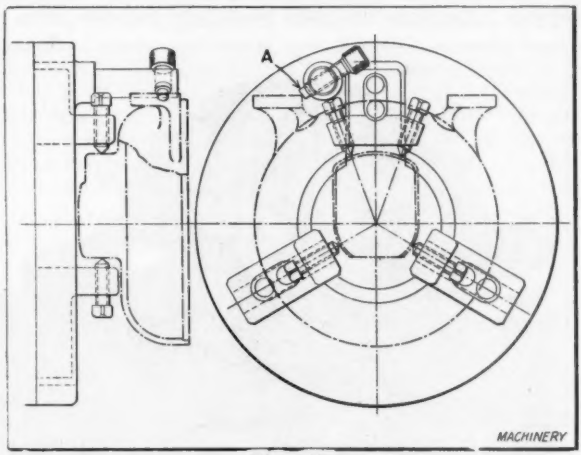

FIG. 15.

on the work, a positive drive being transmitted from the chuck face by an adjusting screw *A*, which is set in contact with the edge of one of the two foot lugs.

Chucking Irregular-shaped Work.

Fig. 16 shows a Forkardt indexing chuck designed for holding valve bodies, cocks, differential spiders, and similar parts. The

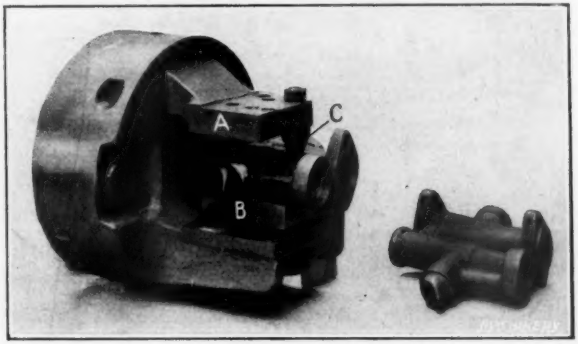

FIG. 16.

chuck has two plunger-type jaws that are actuated by toggle links and a draw-bolt, the faces of the jaws being fitted with pads shaped to suit the contour of the work. The pads rest on flanged studs in the centres of the jaws, the radial position of one stud being deter-

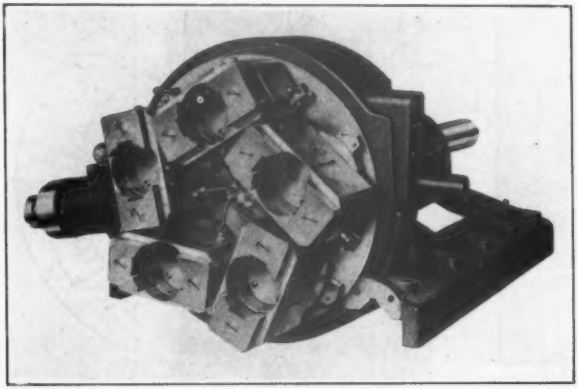

FIG. 17.

mined by a four-way index plate. To effect the indexing movement, the operator first unlocks a key from the index plate, further movement of the wrench turning the jaw round. The key automatically

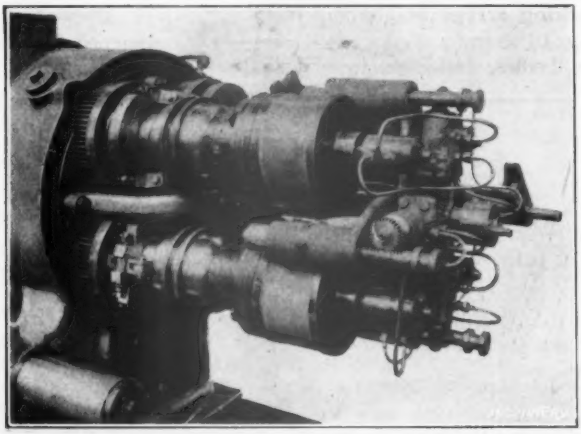

FIG. 18.

engages the next index slot when this reaches the register point.

The two next illustrations indicate the possibility of applying the air chuck to multi-spindle automatic chucking machines. Fig. 17 shows the arrangement of Forkardt two-jaw air chucks on a five spindle Prentice automatic, and Fig. 18 a close-up rear end view of a B.S.A. Tools, Ltd. four-spindle automatic fitted with air chucks. Each chuck is operated by a separate air cylinder, the air supply being controlled by a central stuffing box.

Apart from chucking as applied to lathes and similar machines, there are numerous directions in which air can be used as a clamping medium with greatly increased production.

Git-cutting Machine.

The last example of air-chucking practice is shown by Figs. 19 & 20

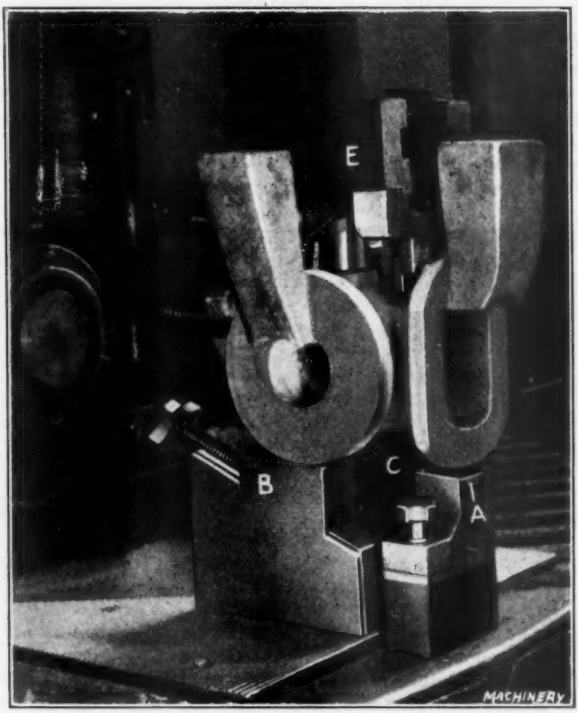

FIG. 19.

which show the use of air on a machine employed for cutting the gits or runners from cast-steel valve bodies. With a view to obtaining perfectly sound joint faces the bodies are cast in such a manner that they are received from the mould with substantial gits on each of the three faces, and after clearing the core sand the first operation consists of removing these by cold sawing. The castings arrive from the foundry in all shapes and sizes, the sawing machines being so designed that the operator takes the castings just as they come to hand and removes the gits irrespective of the shape or size.

The machine consists of a central rotating work table which has four index positions. The table carries four air-operated clamping fixtures and rotates in an anti-clockwise direction.

At the first station the valve body is loaded and adjusted; at the second the first git is cut off by a saw; at the third the gits on the two remaining faces are cut off by a pair of saws, while the finished body is removed at the fourth station.

The method of locating and clamping the bodies is clearly shown. The three flanges are supported by one fixed abutment *A*, Fig. 19, and the two taper wedges *B*-*C*, the latter being adjusted by the hand screws seen to the rear to such a height that the work is approximately level. Having placed the work in position it is squared up by bringing the headstock, Fig. 20. On this

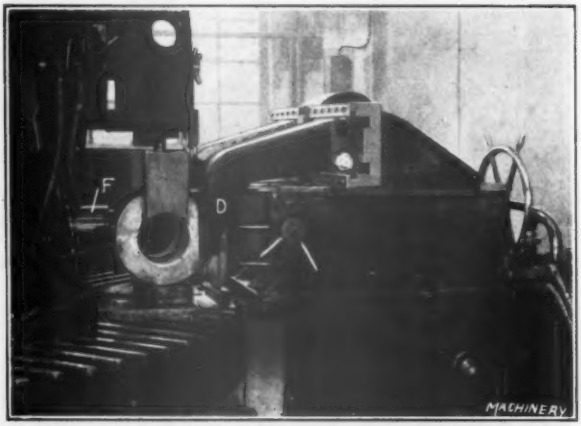

FIG. 20.

there are two adjustable locating abutments that serve to square the front face, and two self-centring side locating members *D*.

These are opened or closed by a hand wheel and embrace the side faces of the body, thus locating the work laterally to suit the twin saws used at the third index station.

To clamp the work the vertically moving rams *E*, Fig. 19, are used. These are fitted with abutments that make three-point contact with the top of the body and are forced down to apply clamping pressure through the medium of toggle links and a central air cylinder, as seen at the bottom left-hand corner in Fig. 20. End thrust on the work, such as is exerted by the twin saws, is taken by a second air-operated clamp, consisting of a ram *F*, which is moved forward to press against the back face of the valve body. The machine is operated by two men, one attending to loading and adjusting and the other to the two sets of saws.

Electro-magnetic Chucks.

The electro-magnetic chuck represents another type of power operated work-holding device that is being rapidly developed and is extensively used for surface-grinding operations. Machines for this class of work are now in use with wheel drives transmitting up to 60 h.p., and with coolant systems delivering up to 50 gallons per minute to the wheel. The latter are invariably of the segmental block type, which introduces a condition of intermittent cutting.

As a result, electrically operated chucks are required to have a much greater magnetic strength than hitherto and must be so constructed as to resist the action of moisture. To meet these conditions, J. H. Humphreys & Sons, Oldham, have developed a new type of magnetic chuck, a feature of which is the one-piece construction of the working face. The effect has been to provide a chuck that will withstand the action of soda and water, which will hold castings or forgings in the rough, and hold pieces that have hitherto been considered unsuitable for the magnetic chuck because of the poor contact surfaces which they possess.

Chucks embodying this new principle are being made in circular types up to 72 inches diameter, and the range is shortly to be extended to include chucks of 84 and 100 inches diameter. Single piece rectangular chucks are made up to 90 inches long by 20 inches wide, and sectionally up to 20 feet long by 18 inches wide. On the smaller sizes, such as are used on tool-room surface-grinding machines, the strength of the grip is such that the work will stand up against the action of a planer or milling cut.

The principal difference between the present and previous types is in the design of the body. This is now cast in one piece, while the magnets are made from steel of high permeability. The material has a magnetic value at least 55 per cent. greater than cast iron, the increased magnetism being utilised to the fullest possible extent by making the magnets of large section and proportioning them with regard to the coil spaces in such a manner as to obtain the maximum

core area. The body is enclosed by a faceplate which is machined from a one-piece steel forging and effectively prevents loosening of the poles or the entrance of moisture when the chuck is built up.

As compared to other types of power chuck, the electro-magnetic chuck is intended purely for face-gripping. In this connection it is extensively used for holding large textile machine frames on

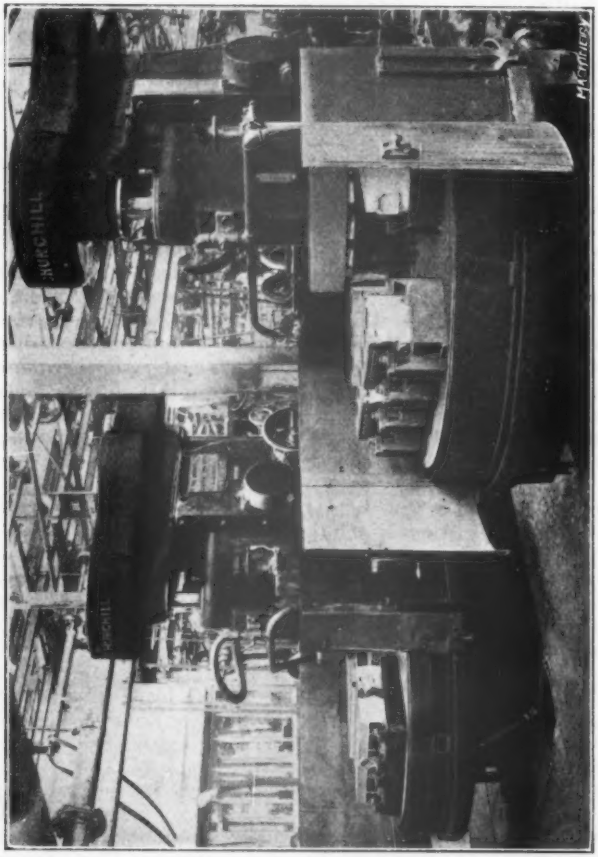

FIG. 21.

surface-grinding machine tables. These castings are not particularly robust and are very easily distorted. The chucks are also being used for continuous grinding such parts as ball-bearing housings and

motor-car clutch plates. In such cases the parts are hopper-fed to the chuck at one side, and are held magnetically while they pass under the grinding wheel. The grip continues until the parts have passed through about two-thirds of the circle, when the pieces are automatically released and are led by a chute through a demagnetising fixture, thus completing the process.

Another direction in which the electro-magnetic chuck is being applied is shown by Fig. 21. This illustrates two Churchill rotary table surface-grinding machines in the plant of Rolls-Royce, Ltd., Derby. The machines are fitted with 63-inch diameter Humphreys magnetic chucks, which are used to hold cylinder blocks, connecting rods, and similar pieces. The pieces of work are mounted in flat bottom fixtures that are gripped by the magnetic action of the chuck and can be loaded on a side bench while the machine is in operation. Non-ferrous castings are treated in a similar manner, and by using a loose fixture difficulties presented by poor surface contact are eliminated and idle machine time is reduced to a minimum.

During the course of this paper, the authors have been mainly concerned with pointing out the possibilities of pneumatic, oil and other forms of power chucking, and even where hand chucking methods have been taken into account, there is no doubt but that some form of power actuation would result in considerable saving. These savings would be apparent for two main reasons : (1) Operator fatigue reduced to a minimum ; (2) additional output secured by a reduction in non-productive time.

It will be noted that operator fatigue has been placed first as a source of time saving, because the strain exerted by the operator using a hand chucking device lowers his or her output figures very appreciably as the working period draws to a close.

It is possible that considerable further saving could be allocated to the use of air, oil or electrically-operated chucking devices due to the conditions of grip outlined under the heading of Work Holding Effect, namely, the ability of the chuck to follow up and counteract the effect of increased cutting pressure. As a consequence, there is a reduced possibility of work being spoilt through work moving in the chuck.

That some form of power operation need not be excessively costly has been clearly emphasised, the price of a complete compressed-air installation for even a moderate-sized shop being negligible when the benefits secured are taken into account. For this reason, it is felt that any further additions to plant that may be contemplated should be considered with power-operated chucks or fixtures as an essential part of the equipment. The only reservation to this statement is that, under certain conditions, a hand operated chuck could be shown to be more economical than a power-operated chuck. A great deal depends on the number of times per hour a chuck has to be operated. It is quite possible that

on machines having a productive time cycle of over ten minutes per piece, a hand-operated chuck would show a saving in cost. On the other hand, by far the greater proportion of machining operations have a time cycle considerably below ten minutes, and in any case, if the time cycle is consistently large, it is possible to effect economies in the power installation. For example, the air compressor required to operate chucks on a six-minute cycle would only need to be of half the capacity of the compressor for chucks operating on a three-minute cycle.

In conclusion, the authors desire to acknowledge the generous assistance of the following firms, in compiling this paper. Alfred Herbert, Ltd., Coventry; H. W. Ward & Co. Ltd., Birmingham; F. Pratt & Co. Ltd., Halifax; A. C. Wickman, Ltd., Coventry; Paul Forkardt, Düsseldorf; Broom & Wade, Ltd., High Wycombe, and Buck & Hickman, Ltd., London.

(NOTE.—*The Institution is indebted to the Editor of "Machinery" for permission to publish the illustrations accompanying this paper*).

Discussion.

THE CHAIRMAN, MR. J. A. HANNAY: I think you will all agree that the slides shown to-night have been very good indeed. I do not believe I have ever been at a meeting where the slides have been as clear. One hardly knows where to start after listening to what the lecturer has been saying, but no doubt many of you have your own particular problems in mind and would like to put some questions to Mr. Field and Mr. Garnett.

MR. TRYHORN: What provision is made on air-operated chucks for safety in the event of a failure of the air compressor?

MR. FIELD: The point raised by Mr. Tryhorn is very interesting, but it should be pointed out that air chucks do not work direct from a compressor, but by pipe lines from a suitable storage tank.

MR. TRYHORN: I wondered whether the leakage would be too great on the cylinder itself, that is, whether the air pressure would so fall as to compel the machine to cease working.

MR. FIELD: I should imagine not, as the mechanical parts of the chuck are practically non-reversible and pieces have been successfully machined with the air pressure entirely cut off after the piece has been gripped.

MR. I. H. WRIGHT: I would like first of all to congratulate Mr. Field and Mr. Garnett on having presented one of the best ordered papers I have ever heard—one that started with fundamentals and has built up to the more complex form in a better manner than is usually done. It seems to me that the main examples of the paper have been the chucking of rotating work through clamp-

ing with air chucks and I believe that Mr. Field stated the case clearly when he said that the gripping edges of the jaws will " bite " into the work as the work is placed in torsion by the action of the cutting tools, whereas with a hand gripping chuck, once it has started to rotate, you have no further opportunity of tightening it. I believe under these circumstances, the air chuck does not require tremendous pressure which you must put on to the ordinary hand operated chuck to meet those circumstances. I consider that the air chuck as ordinarily made with jaws moved by bell crank levers, is not too efficient mechanically, and that the form with the wedge probably requires more air pressure, but is more likely to be safe in use.

Mr. Field mentioned that at least 50 per cent., probably 70 per cent. of the energy put into the closing of the hand chuck is lost in friction. The figure of 70 per cent. is surprisingly high to me. I have closed a few chucks by hand, and the efficiency seemed to me to be about five or ten per cent., which means 90 to 95 per cent. of the energy was not doing much good.

It seems to me air chucking with levers is not so efficient. If any circumstances arise to reduce the air pressure at all, the jaws immediately feel the difference, whereas with the wedge type of chuck, the wedge being mechanically of much lower efficiency, when you have pushed it in with the air piston and obtained the necessary gripping pressure, it is still capable of following up, but if the movement tends to reverse entirely after the air pressure falls off slightly, it has to fall off to quite a light pressure before there is a tendency for jaws to work backwards. It seems to me that is a more promising line for the air chuck than the lever type. I would be interested to know whether Mr. Field supports my view. I am glad Mr. Field showed the Ward bar chuck. I have always greatly admired that chuck. It is a wonderful chuck, and in its later forms should be very successful. I quite expected Mr. Field was going to show us how to put an air cylinder on that well established and fully developed Ward chuck.

With regard to compressors, if you have no compressed air in the works, and are putting in compressor and receiver for the chuck business only, it would seem wasteful. If you already have a compressed air system in the works used for blowing dirt out of holes and working pneumatic hammers, " Windy " drills, and all the other operations one sees about the shops, there are liable to be compression fluctuations. I have known trouble to occur under these circumstances, and it does not seem reasonable, when you have a big compressor running only half or three-quarters the time, to put in another one to supply the chucking business.

I should like to have the opinion of the experts as to the advisability of putting in a large air receiver in the department where the chucks are, to have non-return valve on it so that every time

the general shop supply does not reach the figure it is shut off, and may run for several minutes under the stored pressure. I would also suggest it would be quite possible to have a receiver operating such chucks and to have some kind of whistle or siren which, when the pressure ran to a certain low pressure, would be put into action warning all the people in that department to keep away from those chucks which, I think, would be a hint that they would very much appreciate.

I am not personally concerned with gripping rotating pieces, but I am concerned with holding down pieces for milling. I was interested to see those fixtures fitted with levers which Mr. Field showed, but when you put a piece into a fixture and locate it as well as possible, to keep it from shifting its position, and then grip it down, there is still a possibility of its moving if the grip is momentarily insufficient, and milling is in itself an irregular kind of operation, trying in a number of ways to uproot the work from the fixtures. It seems to me that the cylinders should not work so directly as it is done in the examples shown. There should be some definite locking position, some toggle action, which gets a solid locked grip on the work, which would require reverse pressure to relieve it after milling. I have not tried it, but should be strongly inclined to try and get such a principle into it.

Mr. Field has made several veiled remarks about oil-operated chucks. He has not shown us any. I have had something to do with oil, and suggest that Mr. Field would be doing great service to the users of chucks if he would spend the necessary money in experiments in getting successful oil operated chucking. I think myself one reason why the air chuck has been so successful is that it acts suddenly, and with a slam which bites the jaws into the work. I certainly think that the operation of the ordinary hand-operated chuck is one of the things that is really due to the cut out of the operation of machine tools. It puts a serious strain on the operator and is very liable to cause injury to him. There would be every reason for thanking Mr. Field and his friends for taking out that very undesirable muscular movement.

Mr. R. H. Youngash: I should like to add my little quota to the praise that has already been given to Mr. Field and Mr. Garnett for their excellent paper, more particularly for the splendid projection we have had to-night. I feel that most of us will agree, lock, stock and barrel, with what Mr. Wright has said in regard to the air or, as Mr. Wright said, " veiled mention " of, hydraulically operated chucks, and to those who have not had any experience of air-operated chucks I should recommend you to get one at the first opportunity, because it really is a revelation. Those who have been through the mill know the difficulty one gets with chucks, chucks being one of the sore points of machine tool users as long as I can remember. We have had chucks of this make, that make

and the other make ; each has been hailed in its time as the saviour of the situation, but still chucking remains with us, whether operated by cam, screws, or scroll rings. The air-operated chuck is not entirely without its troubles, but its particular advantage lies in the rapidity with which it can be operated. Of course, you have to take that in conjunction with time occupied in doing the job. If you have a piece which takes twenty minutes to produce, then the saving by using an air-operated chuck is almost negligible. If, on the other hand, an operation takes half a minute, the saving is enormous. With regard to the chucks, more particularly the user of the chuck, one difficulty that has not been mentioned is worthy of consideration, and that is that compressed air is usually fairly well impregnated with moisture, and any of you who have compressed air chucks and propose to leave them for a week or so at Christmas, will be well advised to see that a liberal supply of oil is put into their parts before you shut down. Otherwise you may find it rusted up when you come to start after the holiday. In regard to the question of work coming out. I know from experience that the difficulty is not greater than it is with any other form of mechanism. If the air compression goes down, the amount of noise clearly indicates to the operator that something is wrong in that direction, and that is an advantage over non-mechanically operated arrangements. One other point in regard to magnetic chucking. I should be inclined to criticise the whole operation of grinding in cases of these big chucks. Magnetic chucking is a very useful adjunct in the machine shop, and there are many pieces which could not be produced any other way. I suggest that we put a lamp in circuit with the magnetic chuck in such a way that the lamp immediately goes out if the current is cut off, and you would get little trouble in that direction. We get more trouble from segmental wheel machines. It is interesting to me to see the enormous sizes proposed, and in which they are actually making these chucks.

Mr. Field : Taking a few of the points Mr. Wright raised, first I should like to refer to his alleged " veiled " inferences to hydraulic chucking. I do not know sufficient about hydraulic chucking to talk about it, hence the veiled inferences. It may be possible, I think it is, but on the other hand we are trying to speak to-night of things we can definitely substantiate through our own experiences, and I must apologise for having inserted a reference to hydraulic chucking. I thought it might raise some discussion and that we should all learn something, but apparently no one can tell us anything about it. Of course, we are referring this evening to a figure of 80 lbs. per square inch for actually gripping work. This is apparently the pressure necessary to equal the force which a man can apply using the same size of chuck with the same serrated jaws, giving him anything up to three foot length of gas tube on

his key. In some figures I took a few weeks ago we were actually gripping work weighing about 24 lbs. in two seconds by air, and in thirty-seven seconds by a man with a key. They were only test cuts so I cannot give you any time saving, but presuming the operation is a three-minute one, there is a tremendous saving. On the other hand, as Mr. Youngash points out, if you are only gripping your work every twenty minutes, the saving is almost negligible. On small articles, where your time cycle is particularly low, and there is a rapid variation, you might expect to treble your output with a pneumatic fixture as compared with a hand-operated fixture. As regards playing for safety with a toggle-operated device applied to the air chuck, quite a lot of the air chucks we have shown apply that principle. It is a serious question, but at the same time I think you would rather increase the cost of the thing by playing for safety by any mechanical way. While we all appreciate safety in the shop, I think perhaps it could be carried a little too far along these lines. A point I mentioned is that hydraulically operated chucks would be definitely slower than air-operated chucks. We all appreciate the fact that they would give, I think, a much heavier grip if the grip was required, but on the other hand, on the applications we have shown it has been more a question of speed than operator fatigue that we have tried to prove.

Mr. Youngash mentioned the important point of water in the air, and that is a really serious point that must be watched. To all the air chucks, as fitted to lathes at any rate, and also as fitted to milling fixtures as well, very efficient lubricators are fitted, and so long as you keep these lubricators well filled a sufficient supply of oil is carried to the working parts. Mr. Youngash also mentioned the case when the work actually moves. I am convinced that along these lines considerably less damage occurs in a pneumatic chuck than in a hand chuck, because whilst the jaw can progress further, it is continually pushed into the work. It also cushions any definite jam, thus preventing any damage. Under like circumstances I have actually seen a lathe headstock break through a jam in a mechanically operated chuck. Although I have never seen the same thing with a pneumatic chuck, I feel confident that the actual cushion effect of the air would probably stop the machine without any damage being done. I am afraid I am not an expert on electromagnetic chucks to venture in that direction, but in dealing with the subject as broadly as possible, we felt we must mention them as a method of chucking. One thing surprised me very much, that the makers claim they can guarantee sufficient grip or suction to hold work against planing and milling cuts. I should like to see one of the large milling machines. It is an indication of the tremendous grip one can get along these lines.

MR. H. L. SPINKS: At the last discussion "How would you produce this piece?" Mr. Field mentioned that in his opinion the

two-jaw swivel chuck was no good. This evening he has shown us slides of air operated valve chucks. Does the application of air to the chuck make it a good mechanical proposition? He pointed out one of the defects of the swivel chuck was the fact that the jaws had to be slacked off before they could rotate the piece. With regard to the magnetic tables for surface grinding, one thing we shall definitely gain when we put fixtures on these tables—a man need not walk to the stores to get a bolt to bolt the fixtures down.

MR. FIELD: I also remembered, even as I was reading the paper here, what I said at the last meeting with regard to valve chucks, and even despite the fact that it is air operated, I adhere to what I said at the last meeting—I would not buy it and would not use it. It was put forward as an application of air applied to chucks of that description. I beg to be excused from supporting every design shown on the screen to-night. Both Mr. Garnett and myself are very certain along the lines that air is definitely of considerable use in speeding up production, particularly on short operations, and that is the lesson we have tried to drive home to-night. Save your operators fatigue when you possibly can and you will win in the long run, and also save the actual non-productive time on what type of machine you are using.

MR. H. FELL: Some two years ago I fixed up a pneumatic arrangement on an old lathe for dealing with buffer casings, and from this experience I endorse all the lecturer has said to-night with respect to the rapidity and security of air chucking. I should be glad if Mr. Field could tell me how to apply air chucks to large steel pressings. My experience of magnetic chucks over the last few years has also been satisfactory, and I have never yet had any failures in this direction.

MR. FIELD: Taking the latter question first, I should rather like to see the pressings before passing any definite opinion along those lines. I assume you refer to a three or four-jaw slide simultaneous chuck. The shape of the piece would most affect the type of chuck. A three-jaw is best for concentricity. I was rather interested to hear of your experience on the buffer casing. As a contrast I saw at a works in Birmingham, a wonderful little machine doing final operations on a small brass component, and someone had had the brain-wave of blowing brass swarf away by air. Then he got a stage further and as the air grip on the component was released, blew the component itself into a bin at the other side of the machine. I am glad you have answered an important question and given me the assurance that you have had satisfactory experience on electric and pneumatic installations over two or three years. You should regard both these installations as part of the machine plant, and they should have the care that the plant ought to get. After all, the safety of the operator should be your primary consideration.

MR. J. A. HANNAY : I was particularly struck to see the advance that has been made in the last few years by this method of holding, and my mind went back to the time when I was an apprentice. With a view to saving time, the whole question of these chucks was entered into, and the managing director asked me to walk round the shops and count the number of machines that were actually working. He said I should not find 20 per cent., so out of curiosity I used to go round counting, and struggle as I would I could not find at any time 25 per cent. of the machines working. We have made great improvements since. I would like to congratulate these people who design these various chucks in having developed them and given us that assistance in the works to save time. There are all sorts of means of saving time somehow or other in the shops. It might interest you to know that in 1912 a man came back from America and he had had two days with Henry Ford, and Ford's entire trouble in 1912 was how to move his work about. You have seen now what that has led to, and I especially want to point out to some of our members that this question of holding by air is in its infancy. One of our speakers years ago visualised a way in which operators would double the machine's output at once, and the machine would do its work and similarly hold the work. There are very great possibilities, and I think that for our young members there is a valuable field open for very profitable invention.

MR. WRIGHT : It gives me particular pleasure to propose a vote of thanks to Mr. Field and Mr. Garnett. We are an Institution of Production Engineers, and the production engineer is always at loggerheads with the machine tool man as regards construction and operation and that kind of thing. To-night two of the representatives of the machine tool side of the great production problem have come forward and had a very fair hearing from the production engineers. That is a good sign, and I am glad that Mr. Field and Mr. Garnett have done such credit to the poor machine tool maker. They have shown that the machine tool maker can think consecutively about even so small a detail of machine tools generally as the chucking mechanism.

The vote of thanks was cordially adopted.